IBM

IBM Netfinity PCI Hot-Plug Solutions

Helping you get the most from PCI Hot-Plug technology

Executive Summary

IBM Netfinity® servers continue to bring high-availability features to the Intel-processor-based server market with PCI Hot-Plug technology. IBM Netfinity PCI Hot-Plug solutions[1] give you the ability to add, remove and replace PCI I/O adapters while the system is running. Your Netfinity server remains available while you modify the I/O configuration.

IBM understands your need for industry-standard server solutions. We also know that you can't afford to sacrifice the performance and scalability that your business-critical applications demand. Whether you're launching a business from the Web or extending your current IT investment, you have the same demands for keeping your business up and running 24 hours a day, 7 days a week, 365 days a year.

Over the years, IBM has earned its reputation as a leader in:

- Designing powerful and scalable systems for business-critical, data-intensive environments

- Creating solutions that are designed to provide application availability

- Building technical support infrastructures that include skills, tools and procedures for service and support worldwide

Built on experience gained from decades of large and midrange system leadership, IBM's Netfinity servers allow businesses of all sizes to build a reliable foundation for their networks without sacrificing availability and reliability.

IBM is committed to continued enhancements of Netfinity servers by delivering outstanding **power**, **scalability**, **control** and **service**. Focusing on all aspects of computing enables IBM to help you drive reduced total cost of ownership.

This paper offers a brief tutorial on PCI Hot-Plug technology, discusses IBM Netfinity directions for hot-plug technology and describes the features, advantages and benefits of the IBM Netfinity PCI Hot-Plug solution. Because of the dynamic nature of the computer

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[1] Available on selected models of Netfinity servers.

industry, changes may occur in IBM's actual implementations and timing of product announcements.

What is PCI Hot-Plug Technology?

PCI Hot-Plug technology allows you to insert a PCI adapter into an adapter slot while the power is connected to the host system and while other adapters connected to the host-system bus continue operating. The host system is the machine that contains the adapter slots. The host-system bus is a set of signals that are shared by the I/O adapters.

An adapter slot generally has two types of connections—power and signal. Power connections supply power to the adapter so components can operate. Signal connections transmit data, address and control information. Data signals contain the information a user needs, such as the result of a multiply operation. Address signals tell the destination of the data, the way a post office box number describes the destination of a piece of mail. Control signals allow the adapter and the host to communicate without interfering with each other. For example, a control signal might inform an adapter when the address presented is valid, or it might tell the adapter when it is okay to transmit requested data.

When a computer is first powered on, the adapters are also powered on and subsequently configured. Each adapter is provided with power and a reset signal, which sets the adapter to a known state. Resetting an adapter is like taking out a clean sheet of paper in preparation for writing. Once an adapter is reset, it is ready to be configured.

Each adapter must be configured for operation before the operating system uses the adapter. PCI bus adapters have memory locations that store the configuration information informing the adapter how the host system will address it. Once configured, the PCI adapter responds as the host system presents an address. The PCI adapter also signals the host informing it that the adapter needs service. This control signal is called an *interrupt*.

After the adapter is configured, the operating system can use it. As the operating system takes control of the computer, adapter device drivers are loaded and initialized. A device driver contains the instructions that operate the adapter. When the device driver initializes, it looks for the adapter it is designed to operate. This is called a *bus scan*. When it finds the adapter, the device driver reads the configuration information and saves it to enable future communication with the adapter.

The operating system has services that use the adapters for different functions and communicate with the adapter via the device driver. When an operating system service needs to communicate with a device, such as a disk drive adapter, it signals the device driver to either send data to the adapter or request data from it. Using a disk drive as an example, the operating system has a file-system service that saves and retrieves information for the user. When the user requests the operating system to save information on a disk, the operating system sends a request to the file-system service. The file system prepares the information for the device driver to send to the adapter.

Request to save data

Operating System

Device Driver

Adapter

Control and Data
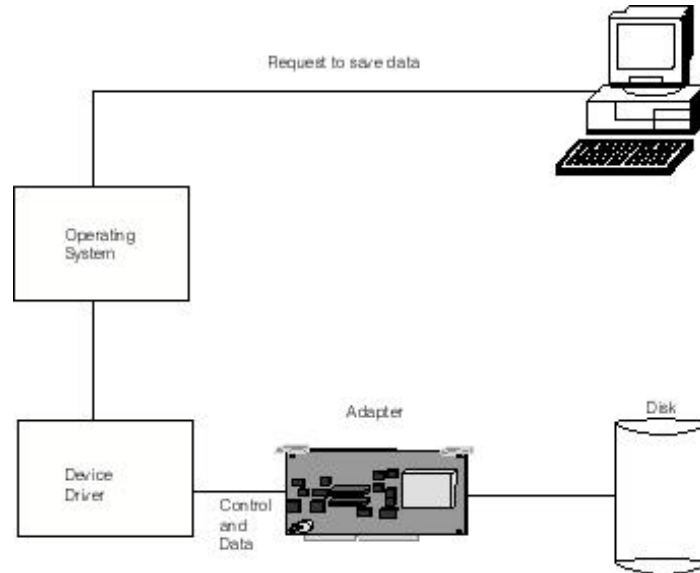
Disk

When an adapter that the operating system is using ceases to operate, problems can occur. For example, if the disk drive adapter fails to respond to device driver requests that were initiated by the operating system, the user might not be able to retrieve the data desired. PCI Hot-Plug technology supports the replacement of this failed adapter while the system continues to operate. After replacement and initialization of the new disk driver adapter, the user can then retrieve the data.

Adapters that are added or replaced while the system is running must be powered on, reset, configured and brought online in an orderly manner. These are the same steps that occur during a traditional system power-up sequence. This process involves loading the device driver for the adapter and starting the appropriate service that uses the adapter. The IBM PCI Hot-Plug solution works in concert with the host operating system to bring adapters online and start their operation.

PCI Hot-Plug functions can be described in two major categories: Hot Add, where an adapter is added to the system to expand capacity; and Hot Replace, where an adapter in the system is no longer operating correctly and is replaced by a similar adapter.

Hot Add Capability: Expand Your System While It's Running

Many growing businesses have experienced the exhaustion of computer resources and determined the need to expand their systems. Traditionally, a system operator will schedule downtime for the system in order to expand the capacity. When a powerful computer—a server—is shared among many users, productivity can be lost when the server is unavailable. The IBM Netfinity PCI Hot-Plug solution is designed to reduce, if not eliminate, the downtime associated with inadequate or missing resources and the associated loss in productivity.

The IBM Netfinity PCI Hot-Plug solution lets you add I/O adapters while the system is still running. For example, if you need to add users or balance your network traffic, you can add a LAN adapter to your Netfinity system. The device driver will be loaded, the service started and users will continue to work uninterrupted.

Today's adapters are well engineered and tested prior to delivery to market. These adapters are rugged and reliable and will generally work well for a long time without failure. With this reliability in mind, IBM focused on expanding the I/O adapter capabilities on the system—without powering down or rebooting the system.

Hot Replace Capability and Fail-over Support

When you buy a computer system for your business, you expect it to operate continuously and reliably. Anyone who uses a computer for work has experienced the frustration of a computer system not being available. High availablity is a must for your business-critical applications. Although it is impossible to guarantee totally uninterrupted service from a server, the IBM Netfinity PCI Hot-Plug solution lets you replace an adapter that has stopped operating or appears to have a problem. When the hot-plug services module recognizes that an adapter has failed, it attempts to unload the device driver and detaches the device from the services using the adapter. The adapter can then be replaced and the new adapter brought online.

There might be cases where some operating system services cannot sustain the loss of an adapter. This varies among different combinations of operating systems, adapters and functions of the adapter. In an effort to move beyond this limitation, IBM implemented a fail-over solution for selected adapters that allows the operating system to continue.

To support the fail-over capability of an adapter, a redundant pair of adapters is used. Two identical adapters (a primary and a backup) are inserted in the I/O expansion slots. A special device driver closely monitors the activities of the primary adapter. If the primary adapter fails, the device driver quickly switches the operations to the back-up adapter. When a failure occurs, the system administrator is notified. The failed adapter can be *hot replaced* and brought back online. Thus, the redundant solution is restored.

For more information about IBM Netfinity fail-over solutions, see our Server Solutions Web page at **www.pc.ibm.com/us/solutions/netfinity/index.html**.

Setting the Standard for PCI Hot-Plug

The PCI Special Interest Group (PCI SIG) is an unincorporated association of members of the microcomputer industry that monitors and enhances the development of the Peripheral Component Interconnect (PCI) architecture. The PCI SIG is lead by a nine-member steering committee, of which IBM is a member.[2]

The PCI SIG chartered a working group to define industry-standard specifications for hot-plug technology. IBM was active in the group's sessions and our contributions were integral to the development of the specifications. The culmination of this work is the *PCI Hot-Plug Specification*, Revision 1.0 released October 6, 1997.

The hot-plug specification provides a standard infrastructure for adding and removing PCI adapters from a computer while the computer is running. It describes the functional modules and their relation to the system. Three major functions are the Hot-Plug Controller, Hot-Plug System Driver and Hot-Plug Service.

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[2] See the PCI SIG Web site at **www.pcisig.com**.

- The **Hot-Plug Controller** is the hardware that controls power and signals to the PCI adapter slot. This controller sequences the power-on and power-off cycles for each adapter slot. When power is applied to the slot, the controller monitors the power to see that the voltages are correct. When the voltages are at the required levels, the controller switches the adapter onto the host system bus. The Hot-Plug Controller monitors each hot-plug slot for a power fault and signals the host system if such an event occurs. The controller also monitors a latch with integrated optical sensors which, if opened or closed, signals a user's intent to remove or add a PCI adapter in the corresponding expansion slot.

  Note: Even though the switch is in place, it is not appropriate to open the switch when an active adapter is installed and the slot is powered. All hot-plug operations are initiated at the system console for orderly operating system interaction with the hot-plug slots.

- The **Hot-Plug System Driver** provides the interface to the Hot-Plug Controller and the Hot-Plug Service. This driver works much like a traditional device driver. It accepts requests from a higher level software component, the Hot-Plug Service, and sends instructions to the Hot-Plug Controller. In addition, it maintains the system configuration and is responsible for configuring the hot-plug adapters.

- The **Hot-Plug Service** is an operating system module that ties together several key aspects of a PCI Hot-Plug solution. The Hot-Plug Service provides a user interface and a program interface for controlling PCI Hot-Plug adapter slots. Information is conveyed to the user about the status of PCI Hot-Plug slots. The operating system vendors provide the Hot-Plug Service and define the software and the interface in their documentation. The program interface, if implemented by the operating system vendor, allows for system management applications to interact with the PCI Hot-Plug solution.

  Note: Not all operating-system vendors will support PCI Hot-Plug in every release of their operating systems.

The following table summarizes the hardware and software functions of the PCI Hot-Plug infrastructure.

	Subsystem	**Functions**
Hardware	Hot-Plug Controller	- Controls power - Connects the adapter to the system - Monitors for power fault
Software	Hot-Plug System Driver	- Maintains the configuration - Presents a common view of the hardware to Hot-Plug Service
	Hot-Plug Service	- Enables user control - Cooperates with other operating system servers - Optionally presents a management interface

Implementing PCI Hot-Plug into a System

IBM offers PCI Hot-Plug in selected models of Netfinity servers. The hot-plug subsystem is composed of IBM-designed hardware and software components that enable hot-plug operations on the server.

Hardware Components

Controller/sequencer. IBM has designed a hardware controller that will manage the power to the PCI adapter slots and the connection of the adapter to the host system.

Power isolation. Even though the solution is commonly referred to as PCI Hot-Plug, the expansion slots are not actually "hot" (powered up and connected to the bus) when adapters are being added or removed. The power is isolated from the expansion slot using power transistors. When an adapter has been safely inserted into the expansion slot, and all connections and cables are affixed, the power is switched on with a user command. Even though the IBM system power supplies are very robust, the power applied to the adapter is brought up slowly rather than instantaneously.[3] A power control module works with the Hot-Plug Controller and the power transistor to smoothly apply power to the adapter. This eliminates power surges, which could potentially upset operation of the system.

Bus isolation. One of the major benefits of having PCI Hot-Plug in the computer is that you can add adapters to the computer without switching it off. To allow other adapters to continue their operations uninterrupted, the power and all other signals to the adapter you're adding are isolated. After the power is applied to the newly added adapter, the system will pause for a very, very short period of time (less than a microsecond[4]) while the new adapter is connected to the system.

Fault detection. The IBM hot-plug solution detects power faults on the hot-plug expansion slots. In the event of a power fault on an adapter, power is removed from the slot almost instantaneously.
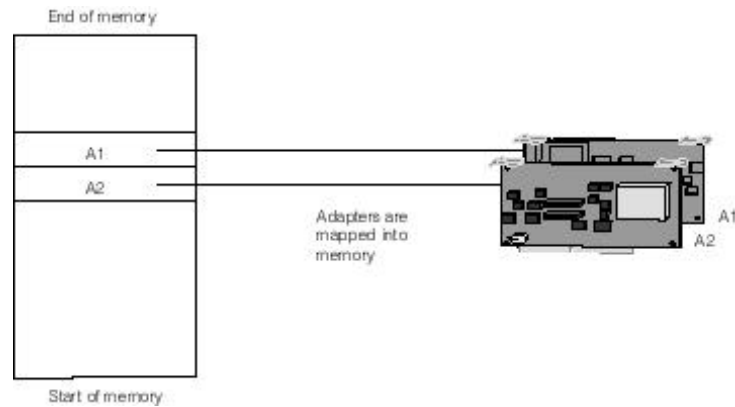
Software Components

Several software components work together to enable hot-plug operations.

Hot-Plug System Driver. After the adapter is powered on and ready to receive information from the host, the adapter is configured. The adapter must be programmed to describe where it resides in the system (its address) and how to signal the host to service the adapter (its interrupt setting). Turning the adapter on and off and configuring the adapter is managed by the Hot-Plug System Driver. This software component, written individually for Novell NetWare, Microsoft® Windows NT® 4.0, and (in the future) SCO UnixWare 7 must always have a compete understanding of the system's configuration. To allocate addresses and interrupts to the adapters, the Hot-Plug System Driver ensures that no two adapters have conflicting resources assigned. It also ensures that the operating system does not try to communicate with the adapter until the adapter is configured correctly. The Hot-Plug System Driver receives commands from the Hot-Plug Service and issues appropriate instructions to the Hot-Plug controller.

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[3] An analogy is using a dimmer to raise the level of lights from off to on rather than a light switch that immediately applies full power to the light.

[4] One-millionth of a second.

Hot-Plug Service. The Hot-Plug System Driver receives instructions from a higher level software component called the *Hot-Plug Service*. You can control the hot-plug expansion slots using the Hot-Plug Service interface. When you issue a command through the interface to perform a task, such as turning on a slot, the Hot-Plug Service instructs the Hot-Plug System Driver to power on, reset and configure the adapter. Then the Hot-Plug Service helps install and initialize the new adapter's device driver.

The Hot-Plug Service presents an interface to the user providing information about the status of the system's hot-plug adapter slots. It can also identify the device drivers that are loaded and identify the adapters located in a hot-plug expansion slot.

Relation of Hot-Plug to Device Drivers

An adapter's device driver is very important in the hot-plug scenario. One of the PCI Hot-Plug specification requirements is for the device driver to *quiesce*. Quiesce means that the adapter driver will not send any requests to the adapter and the adapter will not generate any interrupts or bus activity. This is necessary prior to removing the adapter from the system. The device driver must be written in a manner that supports this quiescence. Operating system vendors who support Hot-Plug PCI are required to design this function into their device-driver specifications. System vendors who provide hot-plug support prior to operating system support must include this function in their device drivers. IBM does this for Microsoft Windows NT 4.0.

Solutions Available

Netfinity ServerProven Program

The IBM Netfinity ServerProven™ program works with industry leaders to test their equipment with ours for compatibility. In our development and test labs, we select and evaluate adapters that meet the needs of our customers for their applications. Current information about adapters that support PCI Hot-Plug and device drivers that support ServerProven adapters is available on the ServerProven Web site at **www.pc.ibm.com/us/solutions/netfinity/index.html**.

Network Operating System Support for PCI Hot-Plug

Microsoft Windows NT 4.0. Because NT 4.0 does not provide operating system support for PCI Hot-Plug operations, IBM has implemented a complete solution for PCI Hot-Plug. We designed a software "stack" that complements our hot-plug hardware and enables NT 4.0 for PCI Hot-Plug operations. We also provided an architecture for the adapter device drivers that includes Desktop Management Interface (DMI) instrumentation for system managment functions. The IBM Kirkland NT Programming Center, located near Microsoft's main development campus in Redmond, WA., designed an innovative solution that not only allows adding new adapters to the system, but also monitors devices that have fail-over capabilities *and* allows remote management of these devices.

Microsoft Windows NT 5.0. With NT 5.0, PCI Hot-Plug is expected to be fully supported under the umbrella of Advanced Configuration and Power Interface (ACPI). ACPI is a specification developed as a result of a collaborative study by Intel, Microsoft and Toshiba. Initially, the study focused on the needs of mobile computing products. However, Microsoft believes that servers will benefit from ACPI as well. The essence of ACPI is operating system-managed power and configuration management. The server's power consumption can be monitored and controlled by the operating system.

The key element of ACPI for PCI Hot-Plug is the configuration management that ACPI offers. ACPI supports the dynamic configuration of adapters added at run time.

IBM will support PCI Hot-Plug for NT 5.0 with the release of Windows NT 5.0 by Microsoft. The software needed to support the IBM hot-plug hardware resides in the system BIOS ROM image. When NT 5.0 loads, it scans the ROM looking for ACPI Machine Language (AML) code. When it finds the AML for PCI Hot-Plug Controllers, the operating system saves the code and uses it when hot-plug events occur. Examples of hot-plug events are:

- When the system operator issues a command to turn a slot on

- If a power fault occurs on one of the hot-plug slots

When the event occurs, the AML code is executed and hot-plug operations begin.

NetWare. NetWare Version 4.11 with Support Pack 5 and NetWare Version 5 will have operating system support for PCI Hot-Plug operations. Device drivers that are written to the ODI 3.31 specification[5] will support PCI Hot-Plug. The operating system will provide a standard user interface where the operator will be able to control the PCI Hot-Plug expansion slots. This interface is between the system operator and the Hot-Plug Service.

To fully realize the potential of the system, IBM has included support for hot add, hot upgrade, and hot replace.

- **Hot add** gives you ultimate flexibility in expanding your Netfinity server without interupting service. For example, if you need to add a network segment and increase the number of users on the server, you can insert the network adapter into

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[5] ODI 3.31 is a device driver specification published by Novell. It describes and governs the implementation of device drivers for NetWare.

one of the available hot-plug slots, connect it to the network (physical medium) and load the device driver and network protocol while the system is running.

- **Hot upgrade** allows you to upgrade an expansion adapter or the device driver that operates the adapter.

- For **hot replace** function, IBM added fail-over capability on selected adapters that allows redundancy on a single LAN segment. In the event of a failure (using a pair of adapters and the appropriate device driver) the LAN segment switches to the backup adapter, and recovery is almost immediate. The system operator is then notified and can *hot replace* the failed adapter. Users on the existing LAN segment should not notice any loss of service. After the failed adapter is replaced and configured, the redundancy is restored.

   A redundant Ethernet solution is possible using the system's built-in 10/100 Ethernet controller[6] and the IBM 10/100 Fault Tolerant Adapter. Using the adapter as the primary adapter and the built-in Ethernet controller as the backup provides a robust network implementation. By using multiple Ethernet adapter pairs in hot-plug expansion slots, you can replace a failed adapter with no loss of service to users.

SCO UnixWare. PCI Hot-Plug support will be available in SCO UnixWare Version 7. The operating system will provide the Hot-Plug Services needed for PCI Hot-Plug support, including a standard graphical user interface (GUI).   Device drivers must be written to the DDI-8 specification and support for PCI Hot-Plug must be added. The DDI-8 spec provides a standard architecture for hot-plug operations, but the hot-plug support is not a requirement for DDI-8 compliance.

IBM will support PCI Hot-Plug on SCO UnixWare when the DDI-8 specification is final and the release of UnixWare Version 7 supports the GUI.

The IBM Netfinity Advantage

Hardware

Although it may seem natural to use the PCI bus as a connection point for the Hot-Plug Controller, IBM has implemented the controller interface on a separate system bus. With this solution, if a PCI expansion adapter causes a problem on the bus, we can still communicate with the Hot-Plug Controller.

In some models of the Netfinity server, an I2C interface is used to read status from the controller. This interface will ultimately allow systems management access to the hot-plug hardware.

To protect the hardware from insertion or removal of adapters with the power on, IBM Netfinity servers are equipped with optical switches. Each PCI adapter slot has an optical switch and a mechanical latch. If you open the incorrect latch by mistake and try to remove an adapter, the Hot-Plug Controller will disconnect the power to the slot. This protects the expansion adapter and the system unit from damage by not allowing an adapter to be removed or installed in an expansion slot with power applied to the slot.

Before you remove an adapter, you must unload the device driver and turn off power to the slot. This is important, because it protects the data and hardware. But in the event

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[6] Available on selected models of Netfinity servers.

that the switch is opened on a powered slot, the power will immediately be disconnected from the slot so the hardware is protected.

Software

IBM created a software stack for Microsoft Windows NT 4.0. Although Microsoft does not support PCI Hot-Plug on NT 4.0, IBM's Kirkland Programming Center worked closely with Microsoft so our PCI Hot-Plug implementation is interoperable with NT 4.0.

IBM is one of the first implementers of PCI Hot-Plug for Novell NetWare, and IBM Netfinity products are among the first to implement PCI Hot-Plug technology. We worked closely with Novell on developing and rolling out this technology. Our efforts with Novell enable a robust implementation of the hot-plug technology and a solution that works cleanly with Novell NetWare.

The IBM Kirkland Programming Center has a close relationship with Microsoft developers implementing ACPI. Our NT 5.0 solution for PCI Hot-Plug, under the umbrella of ACPI, aims to be a complete and robust PCI Hot-Plug solution.

Conclusion

IBM's PCI Hot-Plug technology offers new levels of availability in an Intel-processor-based server. If your business requires a server with a highly flexible and expandable I/O subsystem—that can be modified while the system is running—an IBM Netfinity server with PCI Hot-Plug technology is an excellent choice.

IBM Netfinity servers bring proven large-system expertise and experience to the industry-standard server marketplace. We will continue to enhance Netfinity servers using the skills, experience and technology that only IBM can offer to help you build a reliable foundation and protect your investments in your networked business systems.

Additional Information

For more information on IBM Netfinity directions, products and services, refer to the following papers and briefs, available from our Web site at **www.ibm.com/netfinity**.

IBM Netfinity Technology Trends and Directions

IBM Netfinity 8-Way SMP Directions

IBM Netfinity Cluster Directions

IBM Netfinity Fibre Channel Directions

IBM Netfinity Server Ultra2 SCSI Directions

IBM Netfinity Server Quality

IBM Netfinity Servers and Intel Architecture

System Management for Servers

At Your Service...Differentiation beyond technology

IBM Netfinity Storage Management Using Tape Subsystems

IBM Netfinity ServerGuide for Netfinity and PC Servers

New dimensions in I/O flexibility

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